Creating a Green Building Ecosystem: The Impact of Local Sustainability Polices

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Abstract

Although there are several important federal initiatives, many sustainability efforts in the United States are enacted by states or municipalities. Some of these policies are structured as regulatory mandates while others offer incentives to drive adoption of sustainability related initiatives. We aim to examine how these sustainability efforts impact commercial real estate, specifically, property-level financial performance. We create an index to measure the intensity of local environmental initiatives by state and estimate the effect of higher levels of sustainability policy adoption on building level NOI, change in NOI, cap rates and mortgage default. We show that green policies are associated with higher valuations and lower initial cap rates at the time of loan origination. However, in terms of performance an increase in green policy intensity is associated with a significantly lower annual property level NOI. This in turn, leads to loans on those properties being more likely to experience severe delinquency. This is the case for both green regulations and green incentives, although the magnitude of these negative effects are larger for regulations. Furthermore, the negative impact of green policy intensity is mitigated for properties that have been recently renovated. The effects remain robust across property types, except for multifamily housing, lodging, and mixed-use properties which experience net positive NOI effects. While previous work has focused on the returns to property-level green renovations or certifications, results provide insight into how local sustainability policy may more broadly impact commercial real estate performance.

1 Introduction

The role of the built environment in sustainability efforts is well established. Collectively, the built environment accounts for 40% of annual global Co2 emissions; 27% is attributable to building operations and the remaining 13% is from materials and construction.[1] Therefore, policies implemented to address environmental issues and climate challenges are often targeted to the built environment and may impact the construction and operation of real estate assets (Zuo & Zhao, 2014). In the United States, some policies are implemented at the federal level, but there is also a patchwork of environmental incentives and regulations enacted by states or municipalities. These policies, either directly or indirectly, may impact commercial real estate valuation and performance. We are interested in exploring if this variation in the intensity of the "green ecosystem" in which a property is location has an impact on returns to commercial real estate investment.

Specifically, we examine US properties that are financed by CMBS, using loan-level data from Trepp, to examine how local sustainability efforts impact property level transactions and performance. We look whether developing a "green building ecosystem" that either incentivizes or mandates sustainable real estate building practices benefits commercial real estate investors in the local areas in which those policies apply. Of course, property owners may pursue building level certifications, such as LEED or Energy Star, but many do not. However, all properties are impacted, to varying degrees, when state policies, such as new regulatory mandates are added, or additional incentives are introduced. Such changes in policy could plausibly impact costs and benefits associated with owning commercial real estate in a given geographic area. These effects could vary among many dimensions, including property type, condition, renovation status, and financing terms.

There is a significant body of existing work on how green labels, such as LEED or Energy Star, impact different aspects of the commercial real estate market, such loan performance and

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[1] https://architecture2030.org/why-the-building-sector/

investment return (Eicholtz et. al 2013; Fuerst and McAlister 2014; Bond and Devine 2016; An and Pivo 2020; Robinson and McAlister 2015; Deng and Wu 2014). Additionally, there are many nationwide efforts to incentivize green building certifications and improvements, such as the Fannie Mae green programs for multifamily properties (Devine and McCollum 2022) as well as mandatory building codes for commercial buildings that address minimum standards for items such as energy and water efficiency.[2] While green building certifications and recognitions have been widely available for many years, buildings with these designations represent only a small fraction of the total built environment.[3] Previous studies have identified many barriers to more widespread adoption of green building technologies; in a review article Darko and Chan (2017) summarize the most reported barrier to adoption include "lack of information, cost, lack of incentives, lack of interest and demand, and lack of GB codes and regulations". At the same time local governments have been rapidly adding both regulations and incentives that broadly target the built environment.

This paper examines the economic effects of energy efficiency policies in the US by exploring the case of state-level sustainability policies. The vast majority of state-level sustainability policies impact the built environment and are therefore of consequence to the commercial real estate industry, even if they do not apply directly to a particular CRE asset. Improvements to energy efficiency of residential and commercial buildings which are subsidized or encouraged can reduce energy consumption for households or businesses. That can reduce fuel poverty and free up funds for other types of consumption or investment. It might make neighborhoods where more sustainability policies are observed more attractive places to work or live, which may result in increases in real estate prices and rents. Furthermore, it can improve the financial position of households or companies allowing better mortgage terms. It also can lead to increases in consumption in the areas where energy efficient policies are implemented – for example a rise in restaurant visits, shop foot traffic, etc.

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[2] https://www.epa.gov/smartgrowth/comparison-green-building-standards

[3] However, there exists a patchwork of both incentives and mandates, at city and municipality levels, beyond those at state levels, that have been implemented in efforts to improve energy efficiency in the built environment.

There is also some evidence that improvements in energy efficiency can also lead to job growth. On the other hand, additional regulations related to efficiency standards could drive up the cost of construction and operations for real property. Even voluntary measures not undertaken could negatively impact those buildings located in areas in which the policy is active through the mechanism of increased labor costs in construction and related industries, due to higher levels of education and expertise developed in a local market.

In terms of existing greenness metrics, Kahn (2007) conceptually design a green city index which incorporates environmental morbidity and mortality, pollution avoidance expenditure, local dis-amenities and ecological footprint. However, as the author admits, due to data unavailability, it remains unviable to construct this index for cities in the US or other geographies. The lack of data imposes limitations on quantitative attempts to assess urban greenness and might explain why existing literature is dominated by case studies (Millard-Ball, 2012). Prior quantitative research attempts to measure greenness are typically use measures of carbon emissions (Glaeser & Kahn, 2010; Pedersen et al., 2021; Zheng et al., 2011). Millard-Ball (2012) uses a set of policy outputs to analyze the environmental performance of urban sustainability strategies. We mainly focus on the greenness variables that are crucial for developing green infrastructure assets and improve sustainability, namely green policies, green capabilities and green ideology of citizens (Brown & Farrelly, 2009; Dhakal & Chevalier, 2017; Roy et al., 2008).

To measure building-level exposure to local sustainability efforts, we create a simple index of green policy concentration using the Database of State Incentives for Renewables and Efficiency (DSIRE), which contains an extensive listing of local and state level financial incentives and regulatory policies relating to energy efficiency. To be clear, we are not aiming to match individual level building participation in every possible incentive program or regulatory mandate, but simply want to create a relative measure of the level of exposure any property has to relevant local sustainability policy, both green incentives as well as mandates.[4]

[4] In future work, we will control for individual building level exposure to well-documented nationally available sources of green premiums, such as LEED or Energy Star certifications, but this analysis is still in progress.

Using data on securitized commercial real estate transactions from Trepp we perform property and loan level analysis – including multifamily housing, office, retail and industrial properties. We assess if properties located in areas with higher levels of exposure to energy efficiency efforts receive more favorable loan terms and are associated with higher net operating income (NOI) than their counterparts in localities with fewer programs. Additionally, we examine if there is a difference between exposure to voluntary versus mandatory local green programs.

We show that properties located in states where more green policies are in place are associated with lower initial cap rates and higher initial valuations. This might be to do with stronger price growth as compared to NOI growth. We show evidence that green policies indeed lead to a significant reduction in annual NOI. This in turn, leads to loans on those properties being more likely to experience severe delinquency. However, for buildings that choose to complete major renovations, the negative effects of green policy intensity on performance are largely negated. Overall, we see that while effects remain robust for most property types, multifamily housing is a winner of those policies, experiencing positive performance effects. However, we see little variation for delinquency by property type.

2 Data

We combine data from various sources to generate a unique property-level dataset. Below we describe the individual datasets used for this analysis.

2.1 DSIRE

Our key independent greenness variable is constructed from policies listed in the Database for State Incentives for Renewables and Efficiency (DSIRE).[5] DSIRE provides a comprehensive listing of green policies for us to utilize we aim to uncover the effect of government's regulations and financial incentives to facilitate the sustainability transition and attract capital for green projects. The focus is on state policies and incentives for renewables and energy efficiency. This is because such programs usually aim to facilitate a sustainable transition in consumption and production

[5] For more information on DSIRE, please see: https://www.dsireusa.org/ .

patterns. The programs are classified into two overarching categories, namely regulatory policies and financial incentives, and are further subcategorized into more detailed types[6]. The most common financial incentive includes a rebate program, grant program, loan program and various tax incentives. These incentives offer monetary benefits to encourage improving energy efficiency. For example, an energy rebate program offers residents rebate for the installation of photovoltaic systems. Regulatory policy might impose mandated targets to improve energy efficiency. For example, the Renewables Portfolio Standard requires electricity providers to source a certain portion of electricity utilities from renewable resources (Upton & Synder, 2017).

We do not match any particular policy to a specific building or tenant. Indeed, while some policies (such as a subsidy or tax rebate offered for installation of solar panels) may be directly selected by a building owner, many of the policies do not directly impact building owners' operational decisions.

Such policies and incentives indicate the local government willingness to support a sustainability transition and can send signals to institutional capital looking to comply with ESG principles. For each state in a given year, we count the cumulative number of renewable and energy efficiency programs recorded by DSIRE database. We only count the programs that are published with a specific start date. If the program has a specified end date, we drop the policy from the count in year after the program sunsets. As states are the focal geographical unit of analysis in this research, we only count the policies that in effect in a given year at the state level.[7] We assume that all states are subject to federal regulations and have access to federal incentives. We define *Green Policies* as the natural logarithm of the cumulative number of those policies plus one.

We map the geographical distribution of state-level green policies used in our analysis by year in Figure 1. There are a few states consistently adopting more green policies consistently over time, such as Pennsylvania, California and New York.

[6] We do not currently use any of the finer levels of policy classification in this draft.
[7] For context, there are approximately 3,000 programs that are controlled at the state level while there are only approximately 250 policies at the municipal level in DSIRE, leading to our choice to focus on state level variation.

Figure 1. Green policies maps

This figure shows the geographical distribution of state-level green policies used in our analysis for each state each year over the period of 2008 to 2021. The green policies data are obtained from DSIRE (at: https://www.dsireusa.org/).

2.2 Trepp

We obtain loan level and property level information from Trepp. Trepp collects information about non-agency CMBS including monthly information about commercial real estate loan performance at the building level.

We use the Trepp data on all types of properties for loans securitized into CMBS which are distributing funds to certificate holders from 2010 to 2020. Some of those loans were originated many years prior to the beginning of our observation period, but very few loans in our sample were securitized prior to 1997. Around 32,000 loans have been securitized in 1997. This number peaked in 2006 at almost 105,000 loans issued in that year. There have been hardly any new securitizations in the GFC years of 2008 and 2009. Since 2010 issuance was back to 21,000 and in 2019 it was 10,000 unique loans.[8]

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[8] Although we examine building performance only from 2010-2020, we do include loans that were securitized earlier. Therefore, the number of observations in the cross-sectional year of securitization is lower than the average number of observations per loan may otherwise suggest. Additionally, our final sample size is substantially

It is worth mentioning that the buildings for which CMBS financing is available are investment-grade. In the Trepp database of properties, it is also worth noting that the properties are more likely to be in large urban areas than not, beyond what population numbers for those MSAs would suggest. For some smaller metropolitan or micropolitan areas we have few or no data points at all. Therefore, the commercial real estate sample we investigate is not a representative sample of all available commercial real estate, or even of all commercial real estate secured with mortgage debt. However, although many commercial properties are financed by other methods, such as bank loans, private equity or with the backing of Fannie Mae or Freddie Mac (in the case of multifamily apartment buildings), the near universe of private CMBS data available through Trepp provides us data on a significant and important portion of the investment grade CRE market.

Additionally, properties in our sample have relatively high occupancy rates, so we assume that an adequate measure of investment and credit performance, as regarded by institutional investors, is the periodic income generated by these properties as well as the default rates of the loans associated with the properties.

The Trepp database contains not only information about the loan and its performance over time, but also information about the building and its cash flow. Building-level variables for which data is available include value of the property at the point of securitization, the net operating income (NOI) at securitization, current NOI for some of the properties, annual occupancy rate of the building, number of units for each multifamily housing, rent area in terms of square feet, the year of construction, a ranking of the quality of the building, the year of the last building renovation, if any, a dummy if major deferred maintenance exists. We create a dummy variable that takes the value of 1 if a renovation has taken place in the past 5 years[9]. We calculate the capitalization rate at the point of loan securitization, i.e. initial cap rate, as the ratio of NOI at securitization and the value of securitization. The valuation at loan origination, which should be,

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smaller than these organization numbers would suggest because many loans do not report building level NOI consistently, one of our key outcomes of interest.

[9] We choose to code a renovation as "recent" if it took place in the past 10 years, because that corresponds roughly to the 50th percentile value of time since last renovation amongst the subsample of properties that have any recorded renovation.

and in most cases for our units, is the same as the price of the property. The time varying NOI is expressed as the NOI per unit, for each year the mortgage remains outstanding. Ideally, we would assess total return of the property. However, the data only contains the estimated value of the building at the point of securitization[10], and we do not have annual data for the value, as periodic revaluations do not take place. We also calculate annual NOI growth rate which is calculated as the NOI change year-on-year divided by the NOI in the previous year. While capital expenditure (CapEx) exists as a category within the Trepp database, there is almost no available information on this variable. Therefore, although an imperfect measure, we attempt to operating and capital expenditures through the dummy which indicates recent renovation as well as the property age and quality (Excellent, Good, Fair or Poor).

We also have information about time-varying loan characteristics. Of most relevance would be the loan-to-value (LTV) ratio at origination and current, the loan interest rate at origination and current, debt service coverage ratio (DSCR) at origination and current, a dummy whether the loan requires a balloon payment, and the age of the loan. There is also information about the status of the loan – whether the loan is 30 days, 60 days, 90 days, 120 days or more days delinquent, real estate owned (REO), or in foreclosure. We construct a severe delinquency variable which takes the value of 1 if the loan has been more than 90 days delinquent, has been in foreclosure or in REO. We use the severe delinquency variable as the main way to assess credit performance.

Trepp reports loan payments monthly, but our measures of interest for property characteristics and NOI are only reported annually. Additionally, many of our other variables, including green policy and socioeconomic controls are also only observed annually, so we collapse the data set to annual observations. Despite the large number of loans in the Trepp database, when we clean the sample and account for properties for which NOI is available for the entire period[11], the sample is substantially reduced in some specifications. Once we filter for availability of data for our variables of interest, we have a sample of approximately of between 100,000-300,000 loan-

[10] For refinanced properties, this is the appraisal value at the time of loan origination. For purchase loans, this value is the actual transaction price for the property.

[11] We exclude loans with large numbers of missing annual NOI observations. However, NOI is often not reported in the year the loan is originated or securitized or in the last year of the loan's history in Trepp, and we retain these observations in our dataset if they otherwise do not have missing values.

year observations between 2010 and 2020 for properties located in the 50 largest MSAs, depending on model specifications.

2.3 Other databases

Our data also contains the exact locations of each building. This enables us to link the loan data with census-tract socioeconomic data to capture local market characteristics; specifically, we use data from the Census 5-percent Public Use Microdata Sample (PUMS) American Community Survey (ACS).[12] The census tract level variables are in annual frequency. Specifically, we include the median rent, the percentage of African-American and Hispanic residents, and percentage of renter-occupied housing. We also use eviction data from the Eviction Lab to calculate the annual eviction rate by census tract. The eviction rate is the percentage of evicted households out of the total households in each tract. Evictions are involuntary moves for renters similar to foreclosures for homeowners. In the case of evictions, the landlord takes the decision to expel the tenant from the property. In most cases evictions occur because the tenant cannot make timely rent payments. The most affected tenants from evictions are typically the poorest. Such households spend on average over 70 percent of their income on rent and utilities according to Eviction Lab.[13] Eviction Lab findings also show that the households that are most at risk of eviction are poor women of color.

2.4 Summary statistics

Table 1 presents the summary statistics of the full sample used in our NOI models. In total, we have approximately 240,000 property-year observations for the time-varying NOI models. We can also observe property values only the point of loan securitization. Therefore, as a result, we

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[12] PUMS is a smaller census of 5 percent of census population which takes place every year as compared to the national census taking place every ten years.

[13] The Eviction Lab is an effort by researchers at Princeton University to understand housing eviction. They have created a comprehensive nationwide database of evictions and eviction filings available for download at https://evictionlab.org/. The data on evictions is based on decisions from civil court cases. The laws surrounding eviction vary substantially from city to city.

do not have time-varying information about property valuation and cap rates and can only provide insights into property valuations and cap rates in a cross-section estimation at the time of the transaction.

On average, across all property types, NOI per square foot (sqft) at securitization and the average annual NOI per sqft (over time and across buildings) are $14.43 and $15.08, respectively. The average rental area of a property in our sample is around 125,000 sqft. The year-on-year NOI growth per sqft is approximately 5%, although the median value is 0%. The average value of the property per sqft at loan securitization is approximately $200. The initial cap rate is 7% per year on average with a standard deviation of one percentage point. About 2% of the loans are in severe delinquency, meaning more than 90 days delinquent.

The average property age is 31 years at the time of the loan-year observation, which corresponds to the average property having been built in 1983. This means that the majority of the buildings in our sample are fairly old and in need of renovation or a retrofit eventually. About 31% of the properties have undergone a recent renovation, which we define as the past 10 years.[14]However, 88% of the property-year observations have a flag that indicates major deferred maintenance. The occupancy rate at loan securitization is 92% which is to be expected given these are institutional properties invested in by major institutional investors. We see annual variation in occupancy rate; the occupancy rate in our sample drops to 90% in some years.

In terms of the loan variables, the average mortgage interest rate for the properties in our sample is 6%. The average LTV ratio at loan securitization is 75% and the DSCR at loan securitization is 1.7, which are all underwriting characteristics consistent with institutional-grade commercial real estate lending. About 98% of the loans are balloon loans. The average loan age is 9 years. The average year of loan origination that we observe in our is 2006, with 95% of our observations for loans that are originated in 1998 or later.

In terms of the green policies, there are on average 19 policies per state and year. The 95th percentile of the total green policies is 31 which the 5th percentile is 8. Every year about 0.7 new

[14] Amongst all observations with any recorded renovation, the average time since the last renovation is 14 years.

policies are enacted. When we look at green incentives versus green regulations, we see a fairly equal average number of 9 and 10 respectively. New green incentives are 0.5 which there are less new green regulations with 0.2 per year. We see a large skew in the marginal green variables, i.e. the "new" variables, with the median in those cases being zero. This suggests that the distribution of new policies is not uniform across states and the majority of the states do not enact new policies each year. While those that enact, introduce more of those.

Table 1: Summary statistics

Variable	mean	sd	p5	p50	p95
Initial NOI per sqft	14.43	9.31	4.08	12.28	31.8
NOI per sqft	15.08	13.33	3.7	11.96	34.58
NOI growth	0.05	0.1	0	0	0.26
securappvaluesqft	199.55	141.76	50.26	162.51	472.74
Initial caprate	0.07	0.01	0.05	0.07	0.1
Severe delinquency	0.02	0.13	0	0	0
Green policies (total)	19.09	7.22	8	19	31
Green policies (new)	0.69	1.11	0	0	3
Green incentives (total)	8.66	5.17	2	8	18
Green incentives (new)	0.49	0.93	0	0	2
Green regulations (total)	10.42	3.11	5	10	15
Green regulations (new)	0.2	0.48	0	0	1
Recent renovation (D)	0.12	0.32	0	0	1
Deferred maintenance (D)	0.88	0.33	0	1	1
Property age	31.28	23.74	7	26	88
propyear	1983.22	23.56	1926	1988	2006
Occupancy rate	0.92	0.12	0.68	0.97	1
rentarea	125442.7	218504.4	9908	61986	448072
Property condition	2.22	0.48	2	2	3
Mortgage rate	0.06	0.06	0.04	0.06	0.08
loanage	8.84	4.17	3	9	16
Origination year of loan	2005.65	4.66	1998	2006	2015
LTV ratio	0.74	0.44	0.45	0.71	1.16
DSCR	1.7	0.62	1.23	1.55	2.65
Balloon	0.98	0.15	1	1	1
Year of distribution of funds to certificate holders	2014.5	2.9	2010	2014	2020
Observations	239043				

In the sample above, the predominant type of property is Retail, about half of the propety-year observations, 110,337. The next larger group is Office with 68,684 properties. This is followed by Industrial with 37,406 properties. In equal amounts of about 10 thousand are multifamily and mixed use. This is different from the entire database, which is dominated by multifamily housing which makes more than one third of the transactions Retail is the second largest group with about one fourth of all observations.

3 Methodology

We have two sets of outcomes the effect of green policies on (1) pricing of properties and (2) their investment and credit performance over time. We first look at initial caprates; specifically, we examine the role of initial NOI and building value at loan origination to assess to what extent the effects are associated with pricing versus NOI. Secondly, we assess the performance over time by looking at annual NOI and mortgage delinquency rates at the building level. The breath of the data puts us in a unique position to explore both, pricing effects as well as performance of buildings which might be influenced by the intensity of green policies in each state.

As discussed above, initial cap rates, NOI at origination and value of the property are not time-varying and therefore our model is conducted as a cross-sectional regression with the dependent variable for different loan vintages. The model is estimated as a pooled OLS regression using a number of property-level controls and fixed effects. Equation (1) illustrates the cross-sectional model:

$$r_{im} = \alpha + \delta * GI_{sm} + \beta * X_{im} + \rho * M_m + \eta * P_p + \varphi * S_s + \omega * C_c + \varepsilon_i \quad (1)$$

r_{im} is the dependent variable which is either the initial cap rate, the NOI at securitization or the value of property *i* at securitization year *m*. In most cases the year of property transaction, the year of loan origination and the year of securitization are the same. Also, in most cases property value is equivalent to the property price. GI_s is the green policy variable, which can be either green policies, green incentives or green regulations. It varies by state *s* and time and is taken for the same year of securitization (*m*) as the dependent variable. X_{im} is a vector of control variables for property *i* at the time of securitization, m. The property variables include the occupancy rate, property size, property age, dummy for recent renovation, dummy for deferred maintenance, property condition.

M_m stands for fixed effects for the year of loan securitization, m. P_p stays for property sector type, i.e. office, multifamily, etc., S_s stands for state fixed effects. C_c stays for county fixed effects. Finally, α is the unknown intercept and ε_i is the error term. We cluster standard errors by property age.

Next, we look at how green policies affect delinquency, NOI per sqft and NOI growth over time. For this purpose, we estimate an unbalanced panel between 2010-2020. The panel is unbalanced as new loans enter the database as time progresses and other loans exit the sample over the sample period. We use random effects and estimate the model using generalized least squares (GLS). We also estimate the baseline model using a fixed effects model and the results remain robust.

Equation (2) illustrates the equation for the panel models:

$$y_{it} = \alpha + \delta * GI_{st} + \beta * X_{it} + \varpi * L_{lit} + \rho * M_m + \Delta * T_t + \eta * P_p + \varphi * S_s + \omega * C_c + u_{it} + \varepsilon_{it} \quad (2)$$

with y_{it} being the dependent variable which is either the log of NOI per sqft, the year-on-year NOI growth rate, or a dummy of the loan is more than 90 days delinquent for property *i* and year of distribution to creditors t. In the panel models we also include additional control variables. In particular, we add loan-level variables, L_{lit} for loan *l*, property *i* and time t. In most cases one loan corresponds to one property but there are some occasions where one loan has been provided for several properties in our database. Loan-level variables for the NOI models only includes the age of the loan. For the delinquency model, we also include a dummy for Balloon loan, the mortgage rate at securitization, the LTV ratio at securitization, the debt service coverage ratio (DSCR) at securitization. An additional property level variable for the delinquency model includes the lagged NOI per sqft in order to control for any other unobserved property characteristics. T_t stands for time fixed effects, and u_{it} is the between-entity error term; ε_{it} is the within-entity error term. We cluster standard errors by property ID.

4 Results

4.1. Baseline results: Impact of Intensity of Green policies

Our baseline results are based on the log of the number of total green policies in a state and year, which is lagged by one year. We report two types of models. First, cross-sectional models of the NOI at securitization, the property value, which in most cases is the same as the price at securitization, and the initial cap rate. Second, unbalanced panel models based on the years of the loan payment distributions to investors spanning from 2010 to 2020.

We also compare the total effect of green policies– the overall number of policies for a given year to the marginal effect of enacting one additional policy – i.e. the new policies in a specific year and that state.

The baseline results are presented in Table 2. We include the effect of total green policies on commercial real estate pricing (panel A) and performance (panel B). Our explanatory variables include the occupancy rate at loan origination, size of the property in sqft, property age in years, a dummy variable whether the property has been recently renovated, a dummy variable whether the property has deferred major maintenance, a categorical variable for the quality of the building ranging from excellent to poor. For the panel models we also include the age of the loan in years. For the delinquency models we also include the LTV ratio at securitization, the mortgage rate at securitization, the DSCR at securitization, whether the loan is a balloon loan and the lagged log of NOI per sqft.

First, we look at the effects of green policies on pricing of commercial real estate in Table 2 panel A. We see that in states where there are more green policies in place the year prior to property transaction, properties that transact in the following year are associated with significantly higher initial NOI and value and significantly lower initial caprates. This might be driven by a stronger growth in commercial real estate prices in those states as compared to the growth in NOI. Overall, at the point of loan origination, investors appear to view properties in areas with higher intensity of green policy at being relatively lower risk, even after controlling for observable property characteristics.

We also look at the remaining explanatory variables in Table 2 Panel A. Properties with higher occupancy rates will be associated with higher NOI, higher values and lower caprates. This suggests that occupancy rate acts as a way of de-risking real estate and hence investors are willing to agree to transact at lower caprates. Similar effects are observed for property size, where larger buildings are associated with lower caprates. However, larger buildings have significantly lower initial NOIs and property values. Older buildings also have lower NOIs and values, as expected. Recently renovated buildings are associated with higher NOI and higher value. The property condition also seems to affect pricing. The worse the property condition is, the lower the NOI and the property price are. The opposite relationship is observed for property condition and cap rates. Overall, the explanatory variables in the baseline model show the expected sign and significance and we will not report those in further robustness regressions for brevity. The results remain available upon request.

Next, we move to the effects of green policies on the performance of commercial real estate. Those are depicted in the panel models presented in Table 2 Panel B. We assess how time-varying green policies affect annual NOI per sqft, the annual growth in NOI per sqft, and severe delinquency (i.e. over 90 days delinquent). We track the same property over time from the point a loan has been securitized, which in most cases is in the same year as the loan origination and the year of purchase or refinance, to the point that the loan drops out of the database, i.e. the loan is repaid or enters foreclosure.

The results in Table 2 Panel B show that properties in states which have had more green policies are associated with significantly lower NOI per sqft (Column 1). This might be because the owners are directly faced with additional expenses to renovate and refurbish the building as a result of new energy efficiency regulations or they indirectly experience increased labor costs in the daily operation of their property, even if the regulations do not directly apply to their property. This will be further explored later in this study.

Although we find a negative impact of green policy intensity on NOI level, we do find a positive impact on year over year growth in NOI for higher levels of green intensity. This result is somewhat puzzling to us, but may be associated with improving efficiency and operations in buildings with greater green policy exposure- leading to higher NOI growth, even though the level of NOI lags behind properties located in lower green intensity.[15]

In column (3) we examine delinquency, for which we have additional loan-level control variables, as listed above, and the lag of the NOI variable. We see that green policies are associated with an increase in probability of severe loan delinquency, even after controlling for the NOI level in the previous year.[16] While the channel which explains this relationship remains beyond the scope of this research, we will assess how property type and renovation status matter for delinquency and how various policies affect delinquency.

[15] Unfortunately, we lack the ability to further disentangle this relationship with the data we are using currently, but this positive NOI growth is consistent and persistent across many different specifications.

[16] In addition, we see that the higher the NOI in the previous year, the lower the likelihood that the property is severely delinquent. It seems that the effect on delinquency might stem from the negative effect of the policies on NOI. With falling NOI, delinquency is in turn be negatively affected.

Table 2: Results for the total number of green policies

Panel A: Cross-sectional regressions

	Log initial NOI per sqft	Log initial value per sqft	Initial caprate
L.Log green policies (Total)	0.1638*	0.1289*	-0.0040**
	-0.0838	-0.0765	-0.0018
Occupancy rate	0.5439***	0.5851***	-0.0076***
	-0.0623	-0.0638	-0.0016
Log size	-0.1002***	-0.1591***	0.0002*
	-0.0096	-0.0086	-0.0001
Property age	-0.0040***	-0.0045***	0.0000***
	-0.0006	-0.0007	0
Recent renovation (D)	0.0708***	0.0461***	-0.0004
	-0.0136	-0.0146	-0.0003
Deferred maintenance (D)	-0.0035	-0.0319*	0.0004
	-0.0154	-0.0163	-0.0004
Property condition=Excellent	0	0	0
	(.)	(.)	(.)
Property condition=Good	-0.1711***	-0.1926***	0.0025***
	-0.0293	-0.0318	-0.0006
Property condition=Fair	-0.1045***	-0.1222***	0.0021***
	-0.028	-0.0289	-0.0006
Property condition=Poor	-0.2825	-0.3257*	0.0034
	-0.1932	-0.1688	-0.0021
Observations	13232	12432	12858
Adjusted R-squared	0.629	0.616	0.427

Panel B: Panel regressions

	Log NOI per sqft	NOI growth	Severe delinquency
L.Log green policies (Total)	-0.0470***	0.0067**	0.0129**
	-0.0086	-0.0031	-0.0058
Occupancy rate	1.1521***	-0.0187***	-0.1098***
	-0.021	-0.0034	-0.0097
Log size	-0.1407***	-0.0019***	-0.0006
	-0.0029	-0.0002	-0.0004
Property age	-0.0045***	0.0001***	0
	-0.0001	0	0
Recent renovation (D)	0.0151***	0.0058***	-0.0044***
	-0.0033	-0.001	-0.0013
Deferred maintenance (D)	-0.0104***	0.0047***	0.0103***
	-0.0036	-0.0007	-0.0011
Property condition=Excellent	0	0	0
	(.)	(.)	(.)
Property condition=Good	-0.0085	0.0113***	0.0017
	-0.0065	-0.0017	-0.0019
Property condition=Fair	-0.0147**	0.0122***	0.003
	-0.0066	-0.0018	-0.0021
Property condition=Poor	-0.0758***	0.0102	0.0013
	-0.0252	-0.0064	-0.0108
loanage	0.0095***	-0.0068***	0.0012***
	-0.0004	-0.0001	-0.0003
Balloon			0.0033**
			-0.0013
Mortgage rate			-0.0040*
			-0.0021
LTV ratio			0.0498***
			-0.0111
DSCR			0.0027**
			-0.0012
L.Log NOI per sqft			-0.0035***
			-0.0011
Observations	299776	225394	116291
r2_w	0.153	0.1024	0.0455
r2_b	0.5696	0.2111	0.0587
r2_o	0.533	0.1388	0.0596

Next, we look at the effect of marginal change in green policies (new policies) on the above variables. Specifically, we are examining the potential impact of a state increasing their policies in a given year differentially, i.e., one additional policy, to say, two additional policies. This variable has been lagged by one year but is not shown in its log form as the size of the variable is in most cases is 0; that is there are many state-year pairs where no new policies are introduced, while in other years several may be introduced together. However, the results remain consistent when using the logged variable. The results are reported in Table 3; the remaining variables have similar effects and are therefore not reported for brevity.

Table 3 shows that marginal policies have no significant effects on commercial real estate pricing or performance. It seems, that enacting more or fewer policies within a state and year is not what drives the impact of green policy on commercial real estate, and it is more about the cumulative number of policies in place in a given state-year pair.

Table 3: Results for the marginal green policies

	Log initial NOI per sqft	Log initial value per sqft	Initial caprate	Log NOI per sqft	NOI growth	Severe delinquency
L.Green policies (new)	0.0088	0.0038	0.0001	-0.0005	0.0001	0.0001
	-0.0061	-0.0054	-0.0001	-0.0004	-0.0002	-0.0003
Adjusted R-squared	0.629	0.616	0.426			
r2_w				0.1528	0.1023	0.0454
r2_b				0.5697	0.2113	0.0586
r2_o				0.533	0.1388	0.0595

4.2 Incentives vs. Regulations

Table 4 presents results where we attempt to disentangle the policy effects depending on whether the policy is associated with new incentives or new regulations. Overall, the results are broadly consistent with our baseline models where we consider all green policies together. We however, do see some differential effects across financial incentives and green regulations. The pricing effect on commercial real estate seems to be associated with the effect from green regulations rather than green incentives; that is investors are agreeing on lower caprates, which might be to do with faster price growth as compared to rental growth, are only influenced by increases in green regulation, not green incentives. However, we do not find significant effects on initial NOI or value when we separate green policies in this manner.

We also see some differential effects in the performance models. Although both higher levels of incentives and regulations are associated with lower NOI, this negative effect is over 3 times the size for regulations as it is for incentives.[17] Additionally, we see that more green incentives are associated with higher NOI growth, but no not find any statistically significant impact for green regulations. Finally, the negative impact of increase in probability of delinquency is statistically significant for both incentives and regulations, but the effect is approximately double the size in regulations as it is in incentives.[18]

The effects on performance of commercial real estate are broadly similar for both green incentives and green regulation. However, the mandatory nature of green regulations might be driving the larger magnitude of the negative impact of this subset of green policies on performance metrics. This could be due to higher construction materials and labor costs more broadly in areas that require higher levels of compliance with green policy. This rise in costs could plausibly impact the performance of commercial real estate buildings that operate in such a market, even if they are not directly required to comply with a particular green policy. However, we leave the precise mechanism to this effect for future research.

Table 4: Regression models with green regulations and green incentives

	Log initial NOI per sqft	Log initial value per sqft	Initial caprate	Log NOI per sqft	NOI growth	Severe delinquency
L.Log green incentives (Total)	0.0571	0.0448	-0.0010	-0.0103***	0.0028**	0.0049**
	(0.0383)	(0.0334)	(0.0007)	(0.0038)	(0.0014)	(0.0024)
L.Log green regulations (Total)	0.1254	0.1046	-0.0079***	-0.0386***	-0.0003	0.0103*
	(0.1140)	(0.1113)	(0.0021)	(0.0096)	(0.0036)	(0.0063)

Following the discussion above, as to whether the negative effect of green policy is on NOI is associated with capex or opex expenditure due to retrofit and refurbishment as a result of the green policy, we perform additional regressions to specifically identify this channel in our two

[17] This difference is statistically significant at the 1% level.
[18] This difference is statistically significant at the 5% level.

key performance metrics of interest, NOI and delinquency. Certainly, the cost and benefit analysis of undertaking any renovation project is a key metric in decision making but is not directly observable. Since we are not able to directly observe the amount spent on capital or operational expenditures, we instead focus on recent renovations as a proxy, while also controlling for the deferred maintenance indicator variable. Additionally, we do not have any information on whether a given renovation is specifically a "green" renovation or if it is response to any specific initiatives offered by the government. To the extent that adoption of green policies locally impacts the effects of a recent renovation on NOI or delinquency, we capture this effect by using an interaction between recent renovation and recent renovation to estimate if there are differential impact of green policy on buildings that are recently renovated. The results are reported in Table 5.

In columns (1)-(3) we present results for NOI for all policies, only incentives, and only regulations, respectively. In each case, we find a significant negative effect on the intensity of green policy, as we did in our baseline model. But in each case, that effect is mitigated for properties that have recently undertaken a significant renovation effort. It seems that the negative impact of higher green policy intensity on NOI is concentrated in properties that have not recently been renovated and are therefore likely to have greater amounts of differed maintenance or operational inefficiencies.

However, we find no offsetting impact of renovation on probability of delinquency, with the interaction term in columns (4)-(6) remaining insignificant throughout.

Table 5: Green policy effects by renovation status

	Policies	Incentives	Regulations	Policies	Incentives	Regulations
	Log NOI per sqft	Log NOI per sqft	Log NOI per sqft	Severe delinquency	Severe delinquency	Severe delinquency
L.Log green policy variable	-0.0457***	-0.0118***	-0.0118***	0.0128**	0.0048*	0.0105*
	-0.0086	-0.0038	-0.0038	-0.0058	-0.0025	-0.0063
L.Log green policy # Recent renovation (D)	0.0356***	0.0232***	0.0232***	0.0014	0.0011	-0.0005
	-0.0078	-0.0046	-0.0046	-0.0032	-0.0019	-0.0041
Recent renovation (D)	-0.0857***	-0.0287***	-0.0397*	-0.0081	-0.0064	-0.0031
	-0.0225	-0.0094	-0.0214	-0.0094	-0.0039	-0.0097
Observations	299776	299776	299776	116291	116291	116291
r2_w	0.153	0.1529	0.1529	0.0455	0.0455	0.0454
r2_b	0.57	0.5701	0.5698	0.058	0.0579	0.0578
r2_o	0.5334	0.5334	0.5331	0.0592	0.0592	0.0592

Next, we turn to assessing how the effect of the green policies, green incentives and green regulations differs based on the property type. As discussed in the Summary Statistics subsection, we have a heterogenous sample of a multitude of property types with retail, office and industrial comprising the majority of our final sample. Table 6 shows that overall, the performance results remain robust, with NOI per sqft being negatively impacted by the green policy variables and probability of severe delinquency also increasing in areas with higher intensity of green policy. However, this is not universally true. We interact our green policy variable with property type and find positive impacts of green policy intensity on NOI in multifamily, lodging, and mixed-use properties.[19] We do not see differential effects by property type for delinquency in most cases, and in no case does the marginal impact of a property type offset the baseline increase in default probability associated with green policy intensity.

Table 6: Green policy effects by property type

[19] Each regression includes fixed effects for property type.

	Policies	Incentives	Regulations	Policies	Incentives	Regulations
	Log NOI per sqft	Log NOI per sqft	Log NOI per sqft	Severe delinquency	Severe delinquency	Severe delinquency
L.Log green policies (Total)	-0.0516***	-0.0146**	-0.0347**	0.0123**	0.0037	0.0126**
	-0.0128	-0.0065	-0.0151	-0.0056	-0.0025	-0.0061
Industrial # L.Log green policy variable	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Lodging # L.Log green policy variable	0.3176**	0.2010**	0.2117	-0.0047	0.0002	-0.0080*
	-0.1435	-0.0807	-0.1371	-0.006	-0.0055	-0.0048
Multifamily # L.Log green policy variable	0.1582***	0.0758***	0.2279***	-0.0008	0.0005	-0.0038
	-0.021	-0.0117	-0.0293	-0.0026	-0.0018	-0.0026
Mixed use # L.Log green policy variable	0.0471*	0.0323**	0.0333	0.0068	0.0058*	-0.0024
	-0.0257	-0.0144	-0.0342	-0.0056	-0.0032	-0.0091
Office # L.Log green policy variable	-0.0188	-0.0075	-0.0292*	-0.0031	-0.0011	-0.0042
	-0.0138	-0.0076	-0.0169	-0.0027	-0.0017	-0.0033
Other # L.Log green policy variable	-0.058	-0.0343	0.0354	-0.0063**	-0.0030*	-0.0053
	-0.0785	-0.045	-0.0994	-0.0032	-0.0018	-0.0059
Retail # L.Log green policy variable	0.0062	0.0063	-0.005	0.0033	0.0033**	-0.0013
	-0.0123	-0.0068	-0.0151	-0.0021	-0.0015	-0.0021
Observations	299776	299776	299776	116291	116291	116291
r2_w	0.1531	0.153	0.153	0.0456	0.0456	0.0454
r2_b	0.5619	0.5617	0.5617	0.0583	0.0582	0.0579
r2_o	0.5263	0.5262	0.5262	0.0592	0.0592	0.0592

5 Conclusion

Exposure to environmentally-sensitive policies vary substantially across states and across time, which provides an environment in which we can disentangle the differential impacts of intensity of green policy on the existing commercial real estate stock. We show that properties located in states where more green policies are enacted, are associated with higher NOI and valuation and lower initial cap rates, providing evidence that investors view properties located in these environments as relatively lower risk. However, we document a strong negative impact on green policy intensity for performance of commercial real estate as a whole, as measured by NOI level and probability of loan delinquency. These effects are significantly larger for areas with higher level of green regulations (mandatory) as compared to areas that have higher levels of green incentives (voluntary).

However, the story is more nuanced than that more green policies are bad for commercial real estate investors. We document some instances where being in a more intense “green ecosystem” is beneficial. Specifically, properties that have been recently renovated do not seem to be punished in more intense green policy environments, perhaps providing an impetus to invest in property improvements in environments that in general demand or reward a higher quality of construction, energy efficiency, or other green policies. Finally, multifamily, lodging, and mixed use- all segments that involve residential occupancy to some degree- enjoy higher NOI per square foot in areas with higher levels of green intensity. Taken together, these results provide insight on how green policies impact commercial real estate performance as a whole, not just properties that pursue certifications or green upgrades intentionally. These results have implications for both investors in commercial real estate as well as policy makers considering new incentives or regulations in this space.

References

Alexander, M. M., Sulkowski, A. J., & Wiggins, W. P. (2016). Sustainability & Tax Policy: Fixing a Patchwork of Policies with a Coherent Federal Framework. *Virginia Environmental Law Journal,* 35(1), 1–58.

An, X., & Pivo, G. (2020). Green buildings in commercial mortgage-backed securities: The effects of LEED and energy star certification on default risk and loan terms. *Real Estate Economics*, 48(1), 7-42.

Bond, S. A., & Devine, A. (2016). Certification matters: Is green talk cheap talk?. *The Journal of Real Estate Finance and Economics*, 52(2), 117-140.

Brown, R. R., & Farrelly, M. A. (2009). Delivering sustainable urban water management: A review of the hurdles we face. *Water Science and Technology*, *59*(5), 839–846.

Darko, A., & Chan, A. P. (2017). Review of barriers to green building adoption. *Sustainable Development*, 25(3), 167-179.

Deng, Y., & Wu, J. (2014). Economic returns to residential green building investment: The developers' perspective. *Regional Science and Urban Economics*, 47, 35-44.

Devine, A., & McCollum, M. (2022). Advancing energy efficiency through green bond policy: multifamily green mortgage backed securities issuance. *Journal of Cleaner Production*, 345, 131019.

Dhakal, K. P., & Chevalier, L. R. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. *Journal of Environmental Management*, *203*, 171–181.

Eichholtz, P., Kok, N., & Quigley, J. M. (2013). The economics of green building. *Review of Economics and Statistics*, 95(1), 50-63.

Fuerst, F., & McAllister, P. (2011). Eco-labeling in commercial office markets: Do LEED and Energy Star offices obtain multiple premiums?. *Ecological Economics*, 70(6), 1220-1230.

Glaeser, E. L., & Kahn, M. E. (2010). The greenness of cities: Carbon dioxide emissions and urban development. *Journal of Urban Economics*, *67*(3), 404–418.

Kahn, M. E. (2007). *Green cities: urban growth and the environment*. Brookings Institution Press.

Koebel, C. T., McCoy, A. P., Sanderford, A. R., Franck, C. T., & Keefe, M. J. (2015). Diffusion of green building technologies in new housing construction. *Energy and Buildings*, 97, 175-185.

Millard-Ball, A. (2012). Do city climate plans reduce emissions? *Journal of Urban Economics*, *71*(3), 289–311. https://doi.org/10.1016/j.jue.2011.12.004

Pedersen, L. H., Fitzgibbons, S., & Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics*, *142*(2).

Porter, A. (2015). In search of hidden treasure: Finding funds for building upgrades. *Corporate Real Estate Journal*, 5(1), 79-87.

Robinson, S., & McAllister, P. (2015). Heterogeneous price premiums in sustainable real estate? An investigation of the relation between value and price premiums. *Journal of Sustainable Real Estate*, 7(1), 1-20.

Roy, A. H., Wenger, S. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., Shuster, W. D., Thurston, H. W., & Brown, R. R. (2008). Impediments and solutions to sustainable, watershed-scale urban stormwater management: Lessons from Australia and the United States. *Environmental Management*, *42*, 344–359.

Upton Jr, G. B., & Snyder, B. F. (2017). Funding renewable energy: An analysis of renewable portfolio standards. *Energy Economics*, 66, 205-216.

Zheng, S., Wang, R., Glaeser, E. L., & Kahn, M. E. (2011). The greenness of China: Household carbon dioxide emissions and urban development. *Journal of Economic Geography*.

Zuo, J., & Zhao, Z. Y. (2014). Green building research–current status and future agenda: A review. Renewable and sustainable energy reviews, 30, 271-281.